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PATENT

METHOD AND APPARATUS FOR IMPROVING SHEET FLOW WATER RIDES

Field Of The Invention

The present invention relates in general to water rides, specifically a mechanism and process that provides a flowing body of water having flat, radial, and inclined surfaces thereon of sufficient area, depth and slope to permit surfboarding, skim-boarding, body-boarding, inner-tubing, and other water-skimming activity and, in particular, to several embodiments with means for generated, forming, maintaining, moving and riding said flow of water in a predominantly steady state condition.

Related Applications

This application is a Continuation-In-Part of co-pending U.S. Application Serial No. 07/286,964, filed December 19, 1988 for IMPROVEMENTS IN SURFING-WAVE GENERATORS, to be issued as U.S. Patent No. 4,954,014 on September 4, 1990, which is a Continuation-In-Part of U.S. Application Serial No. 07/054/521, filed May 27, 1987 for TUNNEL WAVE GENERATOR, issued as U.S. Patent No. 4,792,260 on December 20, 1988.

Background of the Invention

For the past 25 years, surfboard riding and associated wave riding activities, e.g., knee-boarding, body or "Boogie" boarding, skim-boarding, surf-kayaking, inflatable riding, and body surfing (all hereinafter collectively referred to as wave-riding) have continued to grow in popularity along the world's surf endowed coastal shorelines. In concurrence, the 80's decade has witnessed phenomenal growth in the participatory family water recreation facility, i.e., the waterpark. Large pools with manufactured waves have been an integral component in such waterparks. Several classes of wavepools have successfully evolved. The most popular class is that which enables swimmers or inner-tube/inflatable mat riders to bob and float on the undulating swells generated by the wave apparatus. A few pools exist that provide large turbulent white-water bores that surge from deep to shallow pool end. Such pools enable wave-riding~~, however~~. However, white-water bore riding is not preferred by the cognoscenti of the wave-riding world, rather the forward smooth water face of a curling or tubing wave that runs parallel to the shoreline holds the ultimate appeal. Although numerous attempts have been made to establish wave-riding on curling waves as a viable activity in the commercial waterpark wavepool setting, such attempts have met with limited success. The reasons which underlie wave-riding's limited waterpark

success is four-fold, 1) small spilling or unbroken waves which are ideal for the mass of novice waterpark attendees are not ideal for intermediate or advanced wave-riders; 2) the larger waves ideal for wave riding have proven prohibitive in cost to duplicate and become inherently more dangerous as their size increases; 3) the curling and plunging waves sought by advanced wave riders require steep and irregular pool bottom configurations that are inherently dangerous and can cause strong deep water current; 4) assuming a compromised and safer wave shape is acceptable to wave-riding participants, wave-riding is ideally a one-man-to-one-wave event that monopolizes an extended surface area. As a consequence of limited wave quality, excessive cost, potential liability, and large surface area to low rider capacity ratios, wavepools specifically designed for waveriders have proven unjustifiable to water park operators.

All wavepools that currently exist in the waterpark industry and the majority of previously disclosed wave-making inventions attempt to duplicate those types of oscillatory waves found naturally occurring at a beach. For purposes of definition, such waves are hereinafter termed "natural waves". Natural waves also include those found occurring in rivers as caused by submerged obstacles e.g., boulders. As known to those skilled in the art, natural waves have specific characteristics capable of mathematical description as a function of wave length, wave height, period, wave angle, velocity, phase speed, break speed, gravity, free surface water elevation, water depth, etc. Additionally, ~~mathematically~~ mathematical descriptions can be provided for a wide range of wave shapes progressing from an unbroken-to-breaking-to broken. Breaking waves, those of most interest to wave-riders, are traditionally classified as either spilling, plunging or surging. Broken waves can either be stationary (e.g., a river impacting on an obstacle creating a stationary hydraulic jump), or moving (e.g., an ocean white water surge or bore characterized by rapidly varied unsteady flow). The shape of a breaking wave is primarily a function of a given set of the aforementioned wave characteristics and the contour of the bottom over which the wave is moving. Beginning wave-riders prefer the smaller gentle spilling wave produced by a gradually sloped bottom surface. Advanced wave-riders prefer the larger plunging breakers that result from a steeply inclined beach. Since there are demographically a greater number of beginning wave-riders and since the wave favored by beginning riders is a product of an inherently safer gentle incline of beach, and since the energy and cost required to produce a small spilling wave is exponentially less that required to produce a large plunging wave, the current genre of wave pools have by

necessity and practicality not been suitable for wave-riding by the more advanced wave rider.

The subject invention aims at creating a "wave shape" that can serve to provide those types of "wave shapes" desired by intermediate to advanced riders. Additionally, the subject invention seeks to accomplish such "wave shape" creation at a fraction of the cost and with an improved margin of safety as compared to that required to duplicate the aforementioned intermediate to advanced natural waves. The reason the subject invention can succeed at its goal is that it does not duplicate natural waves, rather, it creates "flow shapes" that are a result of high velocity sheet flow over a suitably shaped forming surface. This concept of sheet flow formation versus natural wave formation is one of two primary distinguishing factors between the subject invention and the prior art.

This second distinguishing factor focuses on the forces that "drive" a wave rider when he is riding a wave. To this end, the subject invention defines two distinct classes of flow shapes, i.e., deep water flow shapes and shallow water flow shapes. A deep water flow shape is where the water depth is sufficient such that boundary layer effects of the sheet flow over the forming surface does not influence the operation of rider or riding vehicle, e.g., surfboard. Deep water flow shapes can, assuming certain flow forming and flow characteristics (e.g., velocity) are met, duplicate naturally occurring waves. A shallow water flow shape is where the water is of such depth that the surface boundary layer effects of the sheet flow over the forming surface influences the operation of rider or riding vehicle, e.g., surfboard. As contemplated by the subject invention, shallow water flow shapes will never duplicate naturally occurring waves, because there are differing forces that come into play when a rider rides ~~the respective wave or~~ a shallow flow. As the result of those differing forces, the operational dynamics of the subject invention require that for shallow flows the average velocity of the water sheeting over the flow forming surface will always exceed the maximum velocity which would be found in a natural wave. To better explain why the shallow water flow velocity must always be greater than that of a deep water flow, and to further expand on the forces involved when a surfer rides an ocean wave or conversely when a "skimmer" rides a shallow water flow, the following examples are given: On a natural wave (a deep water flow environment) a surfer prior to starting a ride begins to move up the slope of the coming wave by primarily the forces of buoyancy. In order to overcome the forces of fluid drag, the surfer commences to paddle and take advantage of the interaction between the forces of buoyancy and gravity

to provide a forward component to the surfboard and achieve riding speed. Thereafter, maintenance of a steady state position riding normal to the wave front is a balancing act between on the one hand, the ~~while maintaining the same position on the stationary wave requires~~ hydrodynamic lift forces on the bottom of the surfboard ~~and~~ coupled with buoyancy, and on the other hand, ~~to provide the forces to overcome~~ the forces of gravity and fluid drag. ~~Cutting Trimming~~ Cutting/trimming across the wave front (at an angle to the wave front) requires the same balancing act. If one attempts to reproduce the above described scenario in natural flow conditions, a large water depth is required. Likewise, in the laboratory ~~(amusement park)~~ setting this can be accomplished by deep water flows (reference the Killen papers, infra).

Conversely, in a shallow water flow environment, the forward force component of the "skimmer" and skimming device required to maintain a riding position and overcome fluid drag is due to the downslope component of the gravity force created by the constraint of the solid flow forming surface; balanced primarily by momentum transfer from the high velocity upward shooting flow. The "skimmer's" motion upslope (in excess of the kinetic energy of the "skimmer") consists of the force of the upward shooting flow exceeding the downslope component of gravity. In both deep water and shallow water flow environments, ~~Non~~ non-equilibrium riding maneuvers such as cross-slope motion and oscillating between different elevations are made possible by the interaction between the respective forces as described above and the use of the rider's kinetic energy.

The parent inventions to the subject applications have focused upon deepwater flow shapes specific to the performance of "surfing maneuvers". Surfing maneuvers, is defined by those skilled in the art, as those which occur under ocean like hydrodynamic conditions. Consequently, surfing maneuvers can be performed in an artificial environment, e.g., a wavepool, assuming that the wave which is produced duplicates the ocean wave riding experience (deep water flow) as described above. By corollary, true surfing maneuvers cannot be performed in shallow flow environments since the hydrodynamic conditions are distinct. However, full scale tests have demonstrated that the physical look and feel of "surfing like maneuvers" performed in a shallow flow are surprisingly similar to "real" surfing maneuvers performed in a deep flow. For purposes of technical clarity, shallow flow "surfing type maneuvers" shall be termed as a subset of what hereafter can be described as "water skimming maneuvers". Water skimming maneuvers are defined as those activities which can be performed on shallow water flows including "surfing like

maneuvers" as well as other activities or other types of maneuvers with differing types of vehicles e.g. inner-tubes, bodyboards, etc.

The subject invention discloses improvements to the prior art of shallow water flows, as well as ~~,~~ similar improvements to the deep water flow shapes of the parent invention. The parent invention generated two types of stationary flow shapes, i.e., a stationary peeling tunnel flow shape for advanced waveriders, and a stationary non-breaking upwardly inclined flow shape for beginners. ~~One aim of the subject invention is to apply the principals of shallow flows to the flow forming surfaces of the parent invention. Such improvements are hereinafter referred to as the "Shallow Flow Tunnel Wave Generator" and the "Shallow Flow Inclined Surface."~~

~~A second aim of the subject invention results from connecting specified flow forming surfaces in quantifiable proportions to facilitate increases in rider speed and available rider maneuvers that would be impossible, but for, such proportionately connected surfaces. This deep and shallow water improvement is hereinafter referred to as the "Connected Structure" and the method of increasing ones acceleration is hereinafter termed the "Acceleration Process".~~

~~A third aim of the subject invention is to improve the free flow start capabilities of an inclined flow forming surface by lowering the downstream boundary area of this surface at an angle so as to create a maximum height ridge line of decreasing elevation to facilitate self clearing of undesirable transitory surges, this deep and shallow water improvement is hereinafter referred to as the "Self Clearing Incline".~~

~~A novel ramification to the "Self Clearing Incline" occurs by extending the inclined flow forming surface and associated ridge line of the downstream boundary area to an increased elevation. If such increase in elevation is in excess of the net total head flow necessary to flow over this new increase in elevation, then the flow will form a hydraulic jump and the sub-critical water thereof will spill down the upwardly sheeting flow in the manner of a spilling wave. The fourth aim of the subject invention is to intentionally duplicate this phenomena in both deep and shallow flow environments. Such improvement is hereinafter called the "Inclined Riding Surface with Spilling Wave")~~

~~A fifth deep and shallow water flow improvement of the subject invention is the combination of tunnel and inclined flow forming surfaces, as well as, creation of an intermediate "spilling wave" that works in combination with the inclined surface. Such embodiment is hereinafter referred to as the "Omni Wave". A further feature of the~~

~~Omni-Wave embodiment is its unique flow forming shape can permit (by way of changes to the head of the sheet flow) the transformation of the sheet flow from a stationary "spilling wave" to a combination "spilling wave" and inclined planar wave shape, and ultimately to a combination inclined surface and tunnel wave shape. This unique feature is hereinafter referred to as the "Wave Transformation Process".~~

~~A sixth deep and shallow water flow improvement of the subject invention is through selective combination of the above described improvements to form a flow forming configuration that resembles a longitudinally oriented half pipe. This embodiment is hereinafter referred to as the "Fluid Half Pipe." The Fluid Half Pipe offers unique ride characteristics analogous to such configuration in the sports of skateboarding and snowboarding.~~

~~The final aim of the present invention is the positioning of dividers within a Half Pipe or Inclined Surface as described above to provide separation for the individual riders and to prevent a "jet wash" phenomenon that can result in loss of a rider's flow. Such improvement is hereinafter referred to as "Sheet Flow Dividers."~~

<u>Discussion of Prior Art</u>

The water recreation field is replete with inventions that generate waves yet lacking as to inventions that create flow formed wave-like shapes. In all cases, none to date describe the improvements contemplated by the subject invention, as an examination of some representative references will reveal.

To facilitate distinction, the prior art can be divided into seven broad wave or wave shape forming categories:

Category 1 - an oscillating back-~~an~~ and-forth or periodic up-and-down movement by an object or pressure source that results in disturbance propagation from point to point over a free water surface. Representative prior art: Fisch U.S. Pat. NO. 1,655,498~~, issued Jan. 10, 1928, describes an artificial surf bathing pool in which a tank was shown adapted to rock with a shifting fulcrum in order to create a wave which breaks over bathers in the tank.~~; Fisch U.S. Pat. No. 1,701,842~~, issued Feb. 12, 1929, describes an artificial surf bathing pool comprising a tank adapted to cyclically oscillate on a knife edge in order to induce a surge of water towards the ends of the tank.~~; Keller U.S. Pat. No. 1,871,215 ~~issued Aug. 9, 1932, discloses a machine that causes a log to roll into a pool of water, the displacement of which produces the desired wave motion and surf for bathers in the pool.~~; Matrai U.S. Pat. 3,005,207~~, issued Oct. 24, 1961, discloses a swimming pool with an~~

~~oscillating paddle in a deep chamber which provides simulated ocean waves for the enjoyment of bathers in both deep and shallow portions of the pool, respectively.~~; Anderson U.S. Pat. No. 3,477,233~~, issued Nov. 11, 1969, discloses a machine that periodically moves an elongated rotating buoyant member resulting in gravity waves on the surface of a liquid, for use in mixing liquids, causing mass transport of floating surface matter, and breaking up ice formations.~~; Presnell et al U.S. Pat No. 3,478,444~~, issued Nov. 18, 1969 describes a simulator device for studying and demonstrating wave, current, and wind action on and in a body of water, including a plenum chamber which is connect to a pneumatic compressor and valving system to generate sinusoidal wave action on the liquid.~~; Koster U.S. Pat. No. 3,562,823~~, issued Feb. 16, 1971, discloses a wave making machine for swimming pools, which depends upon the back and forth movement of a sub-merged vane in a pool of water to create a wave, and utilizes a resonance effect to minimize energy usage and obtain desired large waves.~~; Anderson U.S. Pat. No. 4,201,496~~, issued May 6, 1980, disclosed a further improvement on the wavemaking machine of Andersen '233, above, which depends upon the periodic up and down movement of a massive body in water to create the desired waves.~~; and Baker U.S. Pat. No. 4,276,664 ~~issued July 7, 1981, discloses an apparatus for wave making which also, like Andersen '496, depends upon periodic up and down movements of a massive body in water to create desirable waves, perhaps exploiting a resonance effect~~. The structure and operation of Category 1 prior art illustrate those types of devices which generate waves in an unsteady flow, i.e., a wave profile which will vary over distance and time.~~ The subject invention provides a steady state wave shape which need not vary over time and does not have a distance of travel component. Furthermore, the structure of the subject invention does not teach disturbance propagation of a wave form from point to point over the free water surface. Consequently, Category 1 prior art has no relevance to the subject invention.~~

Category 2 - a moving hydraulic jump caused by the release of a quantity of water. Representative prior ~~are~~ art: Dexter U.S. Pat. No. 3,473,334~~, issued Oct. 20, 1969 discloses a wavemaking apparatus which depends upon the release of a large volume of water into a pool, with a white water bore created by the shape of the water outlet or the contour of the pool bottom.~~; Bastenhof U.S. Pat. No. 4,522,535~~, issued June 11, 1985, discloses a surf wave generator which depends upon the release of a large volume of water into a pool, with shape of the wave being created by the contour of the pool bottom.~~; and Schuster, et al U.S. Pat. No. 4,538,719~~, issued Sept. 10, 1985, discloses a method and~~

~~pneumatic apparatus which like Bastenhof, also depends upon the release of a large volume of water into a pool for surf wave production, with the wave shape being created by the contour of the pool bottom~~. Although differing in method, the structure and operation of Category 2 prior art is similar to Category 1 in that they generate waves in an unsteady flow, i.e., a wave profile which will vary over distance and time.~~The subject invention provides a steady state wave shape which need not vary over time and does not have a distance of travel component. Furthermore, the wave height as generated by Category 2 devices will diminish as these waves dissipate energy in their line of travel. Conversely, in the subject invention water can be constantly added to the wave form to keep its height constant.~~ As to the issues of water depth, direction of flow and direction of wave spill, the channel or pool bottoms of Category 2 devices constantly change in depth and become more shallow as one moves in the direction of the traveling wave and released water.~~Conversely, in the subject invention as one moves in the direction of water flow up the incline the water becomes deeper and a spilling wave (if present) will spill in a direction that is opposite to the direction of released water flow. For the above stated reasons, it should be evident that Category 2 prior art has not relevance to the subject invention.~~

Category 3 - a stationary hydraulic jump resulting in a spilling wave. Representative prior art: Le Mehaute U.S. Pat. No. 3,802,697 ~~discloses a water filled channel with a wedge shaped wave forming body positioned in the channel so that water which flows over the wedge with requisite depth and velocity is deflected by the upper surface of the wedge to generate a hydraulic jump suitable for surf riding. Le Mehaute shares an attribute of the "Inclined Riding Surface with Spilling Wave" embodiments of the subject invention, i.e., the ability to generate a stationary hydraulic jump resulting in a spilling wave. However, Le Mehaute can be clearly distinguished from the subject invention as follows: The entire thrust of Le Mehaute is the creation of a hydraulic jump in an open channel by abrupt modification of the depth of the channel, e.g., placing an obstruction in the channel. This obstruction, or wave forming means, causes the water which flows thereover to "deflect" and induce a hydraulic jump and associated spilling wave. The physical orientation of the deflecting surface is always oblique to the prevailing direction of water in the channel.~~

~~Conversely, in both deep water flow and shallow water flow embodiments for the subject invention the inclined surface over which water flows by definition does not "deflect" the~~

~~water which flows thereover and is not necessarily oblique to the prevailing direction of surface water flow. Rather, at any given point a super-critical stream of water flows (with a depth profile at that point) predominantly tangential to the surface of the incline. A user who is riding this flow of water is not depending upon an induced hydraulic jump wave to provide an appropriate angled flow upon which to ride, rather the inclined surface itself maintains the requisite angle of flow, irrespective of the presence of any hydraulic jump. In the event a hydraulic jump should form upon the inclined surface of the subject invention e.g., as described in the "Inclined Riding Surface with Spilling Wave", it should be recognized that such formation is not essential to the flow riding experience and is strictly a local phenomena caused by the flow having insufficient kinetic energy to continue up the incline. The spilling wave associated with this hydraulic jump can vary in position along with the incline (e.g., remain frothing at the point of the jump or tumble down to some equilibrium point near the bottom of the incline) dependent upon how efficiently sub-critical water is vented or removed. When expressed in its simplest terms, Le Mehaute creates his hydraulic jump and associated spilling wave by bouncing water off of an inclined surface. The subject invention creates its hydraulic jump and associated spilling wave by conforming water to a non-deflective inclined surface with a portion thereof having height in excess of the net total head (net of friction losses) of the upwardly flowing stream. The deflective angle of incidence which Le Mehaute seeks to produce is exactly the effect that the subject invention seeks to avoid. It is respectfully submitted that on this matter Le Mehaute teaches away from the structure of the subject invention.~~

~~Specific to the shallow flow embodiments of the subject invention, another distinguishing feature centers upon the issue of vehicle/rider buoyancy. The surfboards or boats in Le Mehaute are described as "buoyant carriers" which are then moved by the hydraulic jump created by the wave forming means, thereby simulating surf riding to a rider positioned on the buoyant carrier. Column 2, line 19 through 23. By definition, the depth of the water in Le Mehaute must be sufficient to support the "buoyant carrier" by the forces of displaced water, i.e., buoyancy forces. Conversely, in the shallow water flow embodiments of the subject invention the support for the surfboard/riding vehicle is primarily provided by dynamic hydroplaning pressures created by the interaction between the surfboard, the upward sheeting flow, and the solid surface of the ride forming means. Buoyancy forces serve as a secondary support factor.~~

~~In that Le Mehaute attempts to duplicate a "natural" standing wave, there are specific relationships between the angle of flow relative to the obstacle, the velocity of flow and the overall wave velocity field. These relationships must be maintained or the "wave" as defined by Le Mehaute will not form. Conversely, in the subject invention one need or cannot conform to these "natural wave" specifications. For example, in deep water flows since one can control the velocity of the sheeting water one can choose to exceed the parameters as found in nature. In shallow water flows, by functional necessity, the velocity of the flow must always exceed that which is found in nature at comparable water depths due to the lack of buoyancy forces and the need to substitute the hydrodynamic "ground" and hydroplaning effects.~~

Category 4 - a moving hydraulic jump caused by a moving hull. Representative prior art: Le Mehaute '697 (supra) also disclosed movement by a wedge shaped body through a non-moving or counter-moving body of water, with such movement causing a hydraulic jump and resultant spilling wave suitable for surf-riding. ~~The moving hydraulic jump of Le Mehaute can be distinguished from the subject invention based upon the previous '697 discussion and upon the obvious structural distinction that Le Mehaute teaches movement of the wave forming means while the subject invention remains stationary.~~

~~Forsman U.S. Pat. No. 3,913,332, issued Oct. 21, 1975, discloses a continuous wave surfing facility, which uses a wave forming generator consisting of a single or double plow-shaped blade moving through an annularly-shaped body of water to form surfing waves of desired shape and size. Both single and double wave forming blades are disclosed, propelled by a vehicle which moves along annular rails, submerged or otherwise, and generates a continuous wave for each blade which is suitable for surfing. Multiple generators can be employed to produce serial waves so that several surfers can enjoy the facility simultaneously. Provision is made for changing wave characteristics by changing the horizontal angle of the blades relative to the direction of motion, the leading edge of the blade, whether double or single being hinged. Besides the obvious structural distinction that Forsman's wave forming means moves, while the subject invention remains stationary, there are two other grounds upon which Forsman can be distinguished. First, the translatory white water wave that is formed by Forsman is the product of a massive hydraulic jump that occurs when the moving plow deflects the water through which it passes. As previously discussed in Le Mehaute '697, a hydraulic jump/spilling wave that~~

~~results from deflection is structurally different from a hydraulic jump/spilling wave that results from non-deflective friction and gravity forces acting upon a flow forming surface that is predominantly tangential to the surface flow (the teaching of the subject invention). Second, the structure and operation of Forsman's apparatus exhibits unsteady state wave generation. The subject invention can exhibit steady state wave form generation.~~

Category 5 - a wave shape that simulates a stationary unbroken wave. Representative prior art: Frenzl U.S. Pat. No. 3,598,402 issued Aug. 10, 1971 is perhaps more closely related in structure to the shallow water flow embodiments of the present invention than any of the previously discussed references. Frenzl disclosed an appliance for practicing aquatic sports such as surf-riding, water-skiing and swimming comprised of a vat, the bottom of which is upwardly sloping and has a longitudinal section which shows a concavity facing upwards while a stream of water is caused to flow upslope over said bottom as produced by a nozzle discharging water unto the surface of the lower end of said bottom. Provision is made for adjustment of the slope of the vat bottom around a pivotal horizontal axis to permit the appliance to be adjusted for that sport which has been selected for practice, e.g., water skiing reduced slope or surf-riding increased slope. Provision is also made for varying the speed of the water from a "torrential flow" for water skimming activities, e.g., surfboard riding, to a "river type flow" wherein the speed of the water is matched to the speed of an exercising swimmer. However, Frenzl '402 does not recognize, either explicitly or implicitly some of the problems solved and advantages proffered by the present invention.~~ A comparative analysis of Frenzl's teaching with the structure of the embodiments as describe herein will serve to illustrate substantive differences. In the instance of "torrential flow", Frenzl teaches that the function of his structure,~~

~~"allow(s) the practicing of surf riding and other similar sports, as the sloping of the vat bottom results in the possibility for the water skier to keep his balance in an equilibrium position depending on the one hand, on an upwardly directed force ascribable to the drag or resistance of the carrier board or boards dipped into the stream of water and, on the other hand, on a downwardly directed force produced by the component of the weight of the water skier in a direction parallel with the vat bottom." (Frenzl, Co. 1 lines 49-57, underlining added).~~

~~In the instance of a "river type flow," Frenzl teaches that the function of his structure,~~

~~"allows also practicing swimming. To this end, the swimmer sets the bottom 1 into a slightly sloping position... and he fills the vat almost up to its upper edge. He resorts then to low speeds for the water stream...The stream of water may be adjusted, as to match the speed of the swimmer..." (Frenzl, Col. 4 lines 14-22, underlining added).~~

~~In both flow descriptions, the entire teaching of Frenzl is for the user of the apparatus to be in equilibrium so that aquatic sport equilibrium training can be practiced by the user. Either a user is in static equilibrium while skimming the surface of the water or in static equilibrium when swimming through the water. All adjustments to Frenzl's appliance are directed at creating or sustaining this equilibrium. Conversely, the teaching of the subject invention is to avoid equilibrium. This desire for disequilibrium manifests itself structurally in two separate areas, a "supra-equidyne area" that extends downstream of Frenzl's "equilibrium zone", and a "sub-equidyne area" that extends upstream of Frenzl's "equilibrium zone". The term "equilibrium zone" as used herein is meant to define Frenzl's claimed structure. The "supra-equidyne area" (a structural feature present in the parent invention as well as all embodiments of the subject invention) is defined as that portion of the riding surface wherein the slope of the incline is sufficiently steep to enable a rider to overcome the upwardly sheeting water flow and slide downwardly thereupon. Since Frenzl taught only equilibrium, Frenzl had no need for a structure (i.e., a supra-equidyne area) which by design results in a disequilibrium producing downward slide. In the subject invention, the purpose of such structure is to allow the performance of surfing type maneuvers upon the water that moves up the inclined surface. As is well known to those skilled in the art of surfing, such maneuvers include riding across the face of the surface of the water, moving down the surface toward the lower end thereof, manipulating the riding vehicle to cut into the surface of water so as to carve an upwardly arcing turn, riding back up along the face of the inclined surface of the body of water and cutting back so as to return down and across the face of the body of water and the like. All of such maneuvering activity encompassed with the term "surfing maneuvers" in deep water flow environments and "water skimming maneuvers" in shallow water flow environments is not desired by Frenzl. In fact, Frenzl teaches that his structure (i.e., the equilibrium zone) is specifically designed to minimize the very maneuvers that the subject invention seeks to encourage. Frenzl states:~~

~~"A theoretical and experimental investigation of the appliance has shown as a matter of fact that the position of equilibrium of the user as referred to hereinabove may, under certain conditions, lack stability. It may occur, during operation, that the user changes suddenly the position of the board or boards carrying him with reference to the water surface, for instance when he simulates sudden movements such as turns, side slips, snow ploughs or the like. This may lead to a substantial alteration of the upwardly directed force referred to therein able and thereby either to a sudden sinking of the water skier whose weight has thus become suddenly predominant down to the lower end of the bottom or else in the opposite case, to a rising of the water skier into immediate proximity with the upper end of said bottom. It has been found that the concavity in the longitudinal section of the bottom of the vat cooperates in a positive manner in ensuring stability by introducing into the equation defining the position of equilibrium referred to hereinabove a stabilizing factor..." (Frenzl, Col. 1 lines 68-75 and Col. 2 lines 1-11).~~

~~It is respectfully submitted that Frenzl, in fact teaches away from the structure (supra-equidyne area) of the subject invention in that Frenzl is clearly limited to a training appliance that supports its participants in equilibrium. Furthermore, Frenzl does not seek the "surfing maneuvers" or "water skimming maneuvers" as taught by the subject invention and such maneuvers are rendered difficult, if not impossible, to perform without the proper structure (supra-equidyne area) to facilitate performance thereof.~~

~~Frenzl limits the practice of his aquatic sport to an upward incline (Reference Col. 1 lines 44-47). He further defines his equilibrium zone as a function of the aquatic sport to be performed but in any event limited to a specific range of inclination (Frenzl Col. 3 line 42-45).~~

~~Frenzl teaches that the sport of "surf riding" is further limited to "steeper slopes" (Frenzl Col. 3 lines 59-61). Frenzl does not contemplate the possibility that water flow over a horizontal surface without slope (as defined by the sub-equidyne area) can be used to perform surfing maneuvers as contemplated by the "Connected Structure" embodiment as further described herein. Furthermore, theoretical and experimental investigation of a prototype embodiment of the "Connected Structure" has shown that proper integration of supra-equidyne area, equilibrium zone and sub-equidyne area results in synergism, i.e., the Connected Structure as a whole enable the performance of surfing maneuvers far superior~~

~~to that which can be accomplished by its respective parts. It is respectfully submitted that Frenzl teaches away from the sub-equidyne structure as taught by the subject invention.~~

Frenzl U.S. Pat. No. 4,564,190 issued Jan. 14, 1986 shows improvements to the appliance for practicing aquatic sports using gliding devices (as disclosed in the Frenzl '402 patent) by introduction of a device that removes water from an upwardly sloping bottom surface which has been slowed down by friction at the boundary faces and returns the water to a pumping system to thereby increase the flow rate and thus eliminate the delirious effects of slowed down water.~~ The improvements as described by Frenzl '190 have no relevance to the subject invention.~~ Frenzl U.S. Pat No. 4,905,987 issued Mar. 6, 1990 shows improvements to the appliance disclosed in the Frenzl '402 patent (described above) by showing connected areas for swimming, non-swimming and a whirlpool so that water from the Frenzl '402 appliance is further utilized after outflow thereof. The primary objective of the Frenzl "987 patent is to improve the start and exit characteristics of the Frenzl '402 appliance by providing a means whereby a user can enter, ride, and exit the appliance to avoid breakdown of the torrential flow.~~ The improvements as described by Frenzl '987 have no relevance to the subject invention.~~

Category 6 - a deflective wave shape that simulates a stationary tunnel wave. Representative prior art: Hornung, ~~J.G~~ H.G. and Killen, P., "A Stationary Oblique Breaking wave for Laboratory Testing of Surfboards", Journal of Fluid Mechanics (1976), Vol. 78, Part 3, pages 459-484. ~~)~~ P.D. Killen, "Model Studies of a Wave Riding Facility", 7th Australasian Hydraulics and Fluid Mechanics Conference, ~~Brisbanee~~ Brisbane, (1980). P.D. Killen and R.J. Stalker, "A facility for Wave Riding Research", Eighth Australasian Fluid Mechanics Conference, University of Newcastle, N.S.W. (1983). The apparatus taught by Killen (all three articles will be collectively referred to as Killen, and each article is specifically referenced by chronological date of publication) forms a wave shape of the type favored by surfboard riders, by placing a suitably shaped fixed position obstacle in a channel of specified width and in the path of a flow of water with specified depth and velocity such that deflection of the water off the obstacle duplicates the geometric and hydrodynamic aspects of a surface gravity wave that is obliquely incident to a sloping beach. At first glance, it may appear that structure as taught by Killen and that as disclosed by the subject invention are substantially similar. However, close examination will reveal significant differences~~, the first of which centers upon the orientation of the flow forming surface to the direction of water flow and the consequences that result~~

~~therefrom. At page 464 of the 1976 article, it is stated, "The final form of the obstacle is shown in figure 3 in the form of a contour map. It can be seen that only a slight curvature has been built into the contours on the obstacle face and that the tip builds up gradually in a backward sweep, leaving a space for the channel wall boundary layer to be washed past outside the region of interest." By visual analysis of Killen's Figure 3 and Figure 5 (wherein Figure 5 shows the obstacle of Figure 3 in operation), it is indicated that the angle of incidence of water impacting the obstacle ranges (depending upon the depth of the flow) from tangential to near perpendicular along the y axis and from near perpendicular to approximately 45 degrees along the x axis; consequently the water striking the obstacle forms a curling flow by deflecting in a range from upward to backward to simulate the ideal surfing type wave. At page 462, Killen by analogy to a gas flow states, "a stationary oblique wave may be generated by deflecting the flow with a wedge." Clearly, Killen teaches that the structure of his obstacle is intended to deflect. The flow lines of Killen separate from the surface over which it flows. Conversely, the subject invention does not deflect water off of an obstacle to form the tunnel wave as taught by Killen, rather the angle of incidence of the entire depth range of sheeting water at a particular point relative to the inclined surface over which it flows at that point is predominantly tangential. Consequently, the water which flows upon the inclined surface conforms to gradual changes in inclination (i.e., a non separated flow). "Conformity" as taught by the subject invention requires that the "tunnel" portion of the subject invention's tunnel flow result from non separation of the flow's surface and sub surface stream lines with causal agent for the "tunnel" attributable to the beyond vertical release angle of the further most downstream edge of the flow forming surface. As demonstrated by Killen, deflection does not require an angle of release that is beyond the vertical in order to form a tunnel wave. To further illustrate this point of distinction, it one were to place a "conforming flow" of the subject invention in operation upon Killen's structure, a tunnel wave could not form because the final angle of release on Killen's structure does not exceed the vertical. When expressed in terms of water depth and obstacle structure vis-a-vis the trajectory of water release at the downstream termination of the obstacle, the composite range in depth of Killen's water flow and its resultant obstacle deflection enables the water flow to bend back and form a tunnel wave without requiring the downstream termination of the obstacle to physically direct and point the flow in an arching upstream trajectory. Conversely, the subject invention creates its tunnel wave by conforming water to a surface of such gradual~~

~~curvature (relative to the flows thickness) that deflection does not occur and the downstream termination of the surface must physically direct and point the flow in the proper upstream trajectory. The deflective angle of incidence which Killen seeks to produce is exactly the effect that the subject invention seeks to avoid. It is respectfully submitted that on this matter Killen teaches away from the structure of the subject invention. Killen goes on to define his optimum wave performance characteristics as a function of water depth, water velocity, channel width and obstacle position. Specific to water depth, Killen states in the 1980 article (page 51) that the water depth of the channel must be "such that the boundary layer on the test section floor does not interfere with the flow around the surfboard fin for suitable range of wave shapes. A maximum channel depth of one half of the maximum wave face height has been found to be adequate." In the 1983 article (page 2B.1), Killen states, "The channel depth must be such that the clearance between the surface of the wave making obstacle and the surfboard hull, when the board is riding on the wave, is sufficient to avoid effects similar to the "ground effect" experienced with very low flying aircraft or the proximity of a wall in wind tunnel testing (e.g., enhanced lift and drag coefficients and increased lift/drag ratio caused by the change in flow direction near the stationary boundary)." Conversely, in shallow flow embodiments of the subject invention there is no requirement for a channel to retain the water flow at a requisite depth. In fact, a preferred embodiment of the subject invention it to project a water flow across an inclined surface without water retaining (channel) walls of any type. Consequently, Killen's defined relationship between the depth of the channel and the wave face height is irrelevant when referenced to the structure of the subject invention. In addition to the foregoing, interference due to boundary layer effects from the floor/wave making obstacle or the surfboard hull/fin is not an adverse concern in the shallow flow embodiments of the subject invention. In fact, the "ground effects" which Killen seeks to avoid are exactly the effects that the subject shallow flow embodiments prefer. It is respectfully submitted that Killen on the point of "ground effects" teaches away from the structure of the shallow flow embodiments of the subject invention. Specific to obstacle position and channel width, Killen states in the 1976 article (page 464) "it is essential to terminate the obstacle about half way across the flume to prevent choking of the flow by the wave." Conversely, in the shallow flow embodiments of the subject invention if one were to place a properly configured inclined surface within a walled channel, the requisite gap between the inclined surface and channel wall could be~~

~~substantially less that the midpoint due to significant reductions in water flow that need flow through the gap. In the 1980 (page 51) and 1983 (page 2B.1) articles, Killen states "Channel width should be about five times the height of the wave face so that the behavior of the model surfboards can be studied over a suitable range of wave surface curvature and steepness." Conversely, in the subject invention, the desired width of flow is subjective. At a minimum, it need only be as wide as is required to perform the desired water skimming activity thereon; for example, if the skimming activity is body surfing, then the width need only be as wide as the human being performing the surfing activity.~~

~~In that Killen attempts to duplicate a "natural" standing tunnel wave, there are specific relationships between the angle of flow relative to the obstacle, the velocity of flow, the depth of flow, and the overall wave velocity field. These relationships must be maintained or the "tunnel wave" as defined by Killen will not properly form, i.e., it would not be a wave that is naturally found in the ocean upon which a surfboard could ride. Conversely, in the subject invention one need or cannot conform to these "natural wave" specifications. For example, in deep water flows since one can control the velocity of the sheeting water one can choose to exceed the parameters as found in nature. In shallow water flows, by functional necessity, the velocity of the flow must always exceed that which is found in nature at comparable water depth due to the lack of buoyancy forces and the need to substitute momentum transfer and hydrodynamic "ground" and hydroplaning effects.~~

In summary, Killen was attempting to create a wave shape that was geometrically and hydrodynamically similar to the ideal wave in the real surfing situation. The "conforming wave shape" as formed by the shallow water flows of the subject invention does not attempt to geometrically and hydrodynamically simulate the ideal wave in the real surfing situation. The "conforming" deep water flows of the subject invention do not require such simulation, even though they can so simulate.

<u>Summary of Invention</u>

To better understand the objects and advantages of the invention as described herein, a list of special terms as used herein are defined:

(1) "deep water flow": that flow whereby the water depth is sufficient such that boundary layer effects of the sheet flow over the forming surface <u>does not significantly influence</u> the operation of rider or riding vehicle, e.g., surfboard. Deep water flow shapes

can, assuming certain flow forming and flow characteristics (e.g., velocity) are met, duplicate naturally occurring waves.

(2) "shallow water flow": that flow whereby the water is of such depth that the surface boundary layer effects of the sheet flow over the forming surface significantly influences the operation of rider or riding vehicle, e.g., surfboard. Shallow water flow shapes will never duplicate naturally occurring waves.

(3) "surfing maneuvers": those maneuvers capable of performance on a surfboard which occur under ocean like hydrodynamic conditions, including deep water flows with the appropriate ocean approximating flow characteristics. Surfing maneuvers include riding across the face of the surface of water on a surfboard, moving down the surface toward the lower end thereof, manipulating the surfboard to cut into the surface of water so as to carve an upwardly arcing turn, riding back up along the face of the inclined surface of the body of water and cutting-back so as to return down and across the face of the body of water and the like, e.g., lip bashing, floaters, inverts, aerials, 360's, etc.

(4) "water skimming maneuvers": those maneuvers which can be performed on shallow water flows including "surfing like maneuvers" (i.e., similar to those described in "surfing maneuvers above) as well as, other activities or other types of maneuvers with differing types of vehicles e.g., inner-tubes, bodyboards, etc.

(5) "body of water": a volume of water wherein the flow of water comprising that body is constantly changing, and with a shape thereof at least of a length, breadth and depth sufficient to permit surfing or water skimming maneuvers thereon as limited or expanded by the respective type of flow, i.e., deep water or shallow water.

(6) "conform (conformed, conforming)", where the angle of incidence of the entire depth range of a body of water is (at a particular point relative to the inclined flow forming surface over which it flows) predominantly tangential to said surface. Consequently, water which flows upon an inclined surface can conform to gradual changes in inclination, e.g., curves, without causing the flow to deflect. As a consequence of flow conformity, the downstream termination of an inclined surface will always physically direct and point the

flow in a direction aligned with the downstream termination surface. A conformed water flow is a non-separated water flow and a deflected water flow is a separated water flow, as the terms separated and non-separated are known by those skilled in the art.

(7) "equilibrium zone": that portion of an upwardly inclined body of water wherein a rider is in equilibrium depending on the one hand, on an upwardly directed force ascribable to the drag or resistance of the riders vehicle or body dipped into the stream of water and, on the other hand, on a downwardly directed force produced by the component of the weight of the rider in a direction parallel with the inclined water forming means.

(8) "supra-equidyne area": that portion of a body of water above the equilibrium zone wherein the slope of the incline is sufficiently steep to enable a rider to overcome the upwardly sheeting water flow and slide downwardly thereupon.

(9) "sub-equidyne area": that portion of a body of water below the equilibrium zone that is predominantly horizontal. In the sub-equidyne area a rider cannot achieve equilibrium and will eventually (due to the forces of fluid drag) be moved back up the incline.

One object of the present invention ~~it~~ is to improve upon the parent invention by providing a flow forming surface upon which a shallow water flow can produce a body of water that is similar to the kind prized by surfers, i.e., a tunnel ~~waves~~ wave, which has a mouth and an enclosed tunnel extending for some distance into the interior of the forward face of the wave-shape. Such improvement is hereinafter referred to as the "Shallow Flow Tunnel Wave Generator." Heretofore, tunnel waves have only been available to surfers in a natural or deep water flow environment. The subject invention, through proper configuration of a flow forming surface and adequate shallow water flow characteristics (e.g., velocity, turbidity, depth, direction, etc.), can produce wave forms that have similar appearance and ride characteristics as "real" tunnel waves subject to certain ride conditions, e.g., limitation on surfboard fin size. However, the significant cost savings attributive to shallow flow construction and reduced energy consumption outweigh any limitations that may be imposed.

The parent invention also provided for a stationary non-breaking upwardly inclined deep water flow shape for beginners. The subject invention will also improve upon this

embodiment of the parent invention through the use of shallow water flow technology. Such improvement is hereinafter referred to as the "Shallow Flow Inclined Surface." In addition to the significant advantage or reduced cost, additional advantages to the shallow water improvements described above include, increased safety due to reduced deep water pool depth, reductions in water maintenance due to decrease in volume of water treated, and the opportunities to create novel water sports, e.g., flowboarding or inner-tube "bumper cars".

A second object of the subject invention is to provide a flow forming means (hereinafter referred to as the "Connected Structure") comprised of a substantially horizontal flat surface (the sub-equidyne area) that transitions by way of a radial concave arc (the equilibrium zone) connected to the supra-equidyne area (e.g., the inclined plane or tunnel wave generator). The Connected Structure facilitates a riders ability to maximize his forward speed by the riders own efforts of "pump-turning", hereinafter more fully described as the "Acceleration Process". Without benefit of said Connected Structure such increased speed would not be available. The Connected Structure encompasses the complete spectrum of surface flows and wave shapes desired by wave-riding and water skimming enthusiasts. Beginning at one extreme with a flat incline, and progressing by introduction of an increasing array of surface curvatures from the horizontal to the vertical combined with varying attitude and inclination of said surface relative to an upward (or downward~~)~~, as the case may be) flow of water that culminates at the other extreme in a tunnel wave shape. A significant feature of the Connected Structure is how its unique configuration can dramatically improve the performance parameters of the parent invention's inclined Surface embodiment~~, as well as improving the performance parameters of prior art shallow water flow embodiments, e.g., as described by Frenzl. In Frenzl's embodiment, water was sheeted up a vat with an inclined bottom surface. The bottom surface was intentionally configured as an equilibrium zone. The rider was limited to equilibrium maneuvers, e.g., downslope facing with adjustments to one center of gravity resulting in modest motion within the confines of the vat. True surfing maneuvers were not possible given that the water flow did not approximate ocean flow characteristics. Furthermore, water skimming maneuvers were severely limited, although, a rider could practice his ability to balance in equilibrium~~. The parent invention hereto permitted conventional surfing maneuvers~~,~~; however, its structure did not optimally facilitate the generation of forward speed with which to perform such maneuvers. The "Acceleration

Process" as now enabled by the Connected Structure improvement allows such forward speed to be attained. ~~The Acceleration Process permits the rider to gain additional velocity in a manner analogous to how a child on a swing generates additional velocity and elevation. Given that the heart and soul of surfing is to enable a rider to enjoy the feel and power of increased velocity that results from cyclical transition between the supra-equidyne area and sub-equidyne area relative to a position of equilibrium, the Connected Structure is a significant improvement to the parent invention and prior art.~~

A third object of the subject invention is to solve the transient surge problems associated with the ride start-up and rider induced flow decay upon upwardly inclined flow surfaces. This solution results by lowering the downstream boundary area of the inclined flow forming surface at an angle so as to create a maximum height ridge line of decreasing elevation to facilitate self-clearing of undesirable transitory surges. This improvement is hereinafter referred to as the "Self-Clearing Incline."

A fourth object of the subject invention and a novel ramification to the "Self-Clearing Incline" occurs by extending the inclined flow forming surface and associated ridge line of the downstream boundary area to an increased elevation. If such increase in elevation is in excess of the net total head flow necessary to scale this new increase in elevation, then the flow will form a hydraulic jump and the sub-critical water thereof will spill down the upwardly sheeting flow in the manner of a spilling wave. This improvement is hereinafter called the "Inclined Riding Surface with Spilling Wave"). The spilling wave phenomena can also be incorporated into the other embodiments as described herein. A corollary improvement to any spilling wave application is a properly configured vent system to handle the water which spills back down the flow forming surface. If such water remained unvented, it would eventually choke the entire flow. Consequently, to maintain a steady state condition, to the extent that new water flows into the system, then, an equal amount of old water must vent out.

A fifth object of the subject invention is to improve by way of combination the tunnel and inclined flow forming surfaces, as well as, creation of an intermediate "spilling wave" that works in combination with the inclined flow surface. This embodiment is hereinafter referred to as the "Omni-Wave". A feature of the Omni-Wave embodiment is its unique flow forming shape can permit (by way of a progressive increase of the net head of the sheet flow) the transformation of a sheet of water flow from a stationary "spilling wave" along the entire forming means, to a transitional "spilling wave" with

inclined surface flow, to the final inclined surface flow and tunnel wave shape. This method is hereinafter referred to as the "Wave Transformation Process". The Omni-Wave and the Wave Transformation Process will offer an improved environment for the performance of surfing and water skimming maneuvers.

A sixth object of the present invention is to provide an apparatus that will enable riders to perform surfing and water skimming maneuvers in a format heretofore unavailable except by analogy to participants in the separate and distinct sports of skateboarding and snowboarding, to ~~with~~ wit, half-pipe riding. In this regard, the present invention comprises a method and apparatus for forming a body of water with a stable shape and an inclined surface thereon substantially in the configuration of a longitudinally oriented half-pipe. Such improvement is hereinafter referred to as the "Fluid Half-Pipe." A corollary improvement to the Fluid Half-Pipe is to provide an apparatus that permits an increased ~~throughout~~ throughput capacity by increasing the depth of the Fluid Half-Pipe in the direction of its length. This increase in depth will have the added benefit of causing a rider to move in the direction of fall and facilitate his course through the ride.

The final object of the present invention is the positioning of dividers within a Fluid Half-Pipe or Inclined Surface as described above and to prevent a "jet wash" phenomenon that can result in loss of a rider's flow. This "jet wash" phenomenon occurs when a rider who is positioned in the equilibrium or supra-equidyne area of a thin sheet flow gets his flow of water cut off by a second rider positioned with priority to the line of flow. The cutting off of water occurs in thin sheet flow situations due to the squeegee effect caused by the second rider's skimming vehicle. The improvement aids in preventing adjacent riders from cutting off their respective flows of water. Such improvement is hereinafter referred to as "Sheet Flow Dividers."

Other objectives and goals will be apparent from the following description taken in conjunction with the drawings included herewith.

<u>Brief Description of the Drawings</u>

~~*See pages 22a, 22b and 22c*~~

~~Reference Numerals in Drawings~~

~~Tunnel "Wave" Surface~~

~~Stem Portion of Tunnel Generator~~

~~Front Face of Tunnel Generator~~

~~Stern Arch~~

~~Upstream Edge~~

~~Downstream Edge~~

~~Back Surface~~

~~Sub-surface Structural Support~~

~~Flow Direction~~

~~Super-Critical Water Flow~~

~~Transition Point~~

~~Rider~~

~~Tunnel~~

~~Brief Description of the Drawings~~

FIGURE ~~11~~ 1 is a profile view of a Tunnel "Wave" Generator configured for shallow waterflows.

FIGURE ~~12~~ 2 is a contour map of Tunnel "Wave" Generator as set forth in FIGURE ~~11~~ 1.

FIGURE ~~13~~ 3 is a plan view of the range of horizontal attitude with respect to the direction of water flow that the wave generator (as set forth in Figure 1) can take and still form a tunnel wave.

FIGURE ~~14~~ 4 is a view in profile of a typical cross-section disclosing the range of inclination of the forward face of the wave generator (as set forth in Figure 1) with respect to the direction of water and orientation to the vertical.

FIGURE ~~15~~ 5 depicts a rider on the Tunnel Wave Generator.

FIGURE ~~16~~ 6 is a profile view of the inclined surface.

FIGURE ~~17~~ 7 is a cross-sectional view of the inclined surface as shown in FIGURE ~~16~~ 6.

FIGURE ~~18~~ 8 depicts a rider on the Inclined Surface.

FIGURE ~~19a~~ 9a is a profile view of the Connected Structure.

FIGURE ~~19b~~ 9b is a cross-section of FIGURE ~~19a~~ 9a.

FIGURE ~~20~~ 10 depicts a surfer riding an Inclined Surface as improved by the Connected Structure and who is taking advantage of the ~~elevation~~ acceleration process.

FIGURE ~~21a~~ 11a is a profile view of the Self Clearing Incline.

FIGURE ~~21b~~ 11b is a cross-section of FIGURE ~~21a~~ 11a.

FIGURE ~~22~~ 12 is a contour map of the Self-Clearing Tunnel Wave.

FIGURE ~~23a~~ 13a, FIGURE ~~23b,~~ 13b, and FIGURE ~~23c~~ 13c are three views in profile that illustrate in time lapse sequence a self-clearing Inclined Surface.

FIGURE ~~24a~~ 14a and FIGURE ~~24b~~ 14b illustrate in time lapse sequence the self-clearing Tunnel Wave.

FIGURE ~~25~~ 15 is a profile view of the Omni-Wave.

FIGURE ~~26a~~ 16a depicts the Omni-Wave with a spilling wave formed along its entire front face.

FIGURE ~~26b~~ 16b depicts the Omni-Wave with a clear inclined surface and a spilling wave.

FIGURE ~~26c~~ 16c depicts the Omni-Wave with a clear inclined surface and a Tunnel Wave.

FIGURE ~~26d~~ 16d depicts a Body Boarder performing water skimming maneuvers and a surfer performing surfing maneuvers on the Omni-Wave.

FIGURE ~~26e~~ 16e depicts a knee boarder riding the spilling wave.

FIGURE ~~26f~~ 16f depicts a water skier on the inclined surface and an inner-tube rider on the spilling wave.

FIGURE ~~27~~ 17 shows in profile view of a novel embodiment for water sports - the Fluid Half-Pipe.

FIGURE ~~28a~~ 18a shows an elevation of a typical Fluid Half-Pipe.

FIGURE ~~28b~~ 18b shows an elevation of a Fluid Half-Pipe with modified flow forming bottom to assist in capacity and rider through put.

FIGURE ~~29~~ 19 illustrates in profile view an improvement to the Fluid Half-Pipe to assist in increased through put capacity.

FIGURE ~~30~~ 20 shows dividers in a shallow flow to avoid flow "jet wash."

~~Shallow Flow Inclined Surface~~

~~Sub-Surface Structural Support~~

~~Back Surface~~

~~Front Surface~~

~~Down Stream Ridge Line~~

~~Upstream Edge~~

~~Side Edge~~

~~Concave Curvature~~

~~Straight Incline~~

~~Concave/Straight Incline Transition Point~~

~~Straight/Convex Transition Point~~

~~Convex Curvature~~

~~Connected Structure~~

~~Supra Equidyne Area~~

~~Transition Line (dashed)~~

~~Equilibrium Zone~~

~~Transition Line (dotted)~~

~~Sub Equidyne Area~~

~~Surfer~~

~~Self Clearing Incline~~

~~Top Vent~~

~~Self Clearing Tunnel Wave~~

~~Swale~~

~~Transient Surge~~

~~Omni Wave~~

~~Stationary Spilling Wave~~

~~Kneeboard Rider~~

~~Innertube Rider~~

~~Water Skier~~

~~Fluid Half Pipe~~

~~Rider(s) – Dividers~~

~~Front Face – Dividers~~

~~Dividers~~

~~Body of Water~~

~~Water~~

~~Leading Edge~~

~~Down Flow Side~~

~~Flat Section~~

~~Up Flow Side~~

~~Trailing Edge~~

~~Receiving Pool~~

~~Rider(s) - Inner Tube~~

~~Half Pipe Flow Forming Means~~

~~——~~

~~Dam~~

Detailed Description of the Subject Invention

Because the original application, the continuation of the original application and the subject invention are operated in water, and many of the results of its passage there-through, or the propelling of water against the wave or flow forming means thereof, are similar to those caused by a boat hull, some of the terms used in the descriptions hereto will be nautical or marine terms; likewise, from the perspective of physical water dynamics, some of the terms used herein will be hydraulic engineering terms; and finally, from the perspective of ride operation and function, some of the terms used herein will be terms as used in the sport of surfing; all such terms constitute a ready-made and appropriate vocabulary which is generally understood by those skilled in the art. To the extent that there are special terms, then, those terms are further defined herein.

Further, it will be understood by those skilled in the art that much of the description of structure and function of the wave generator and inclined surface of the original application and its continuation application may apply to the embodiments of the subject invention, to the extent used by this application, Therefore, the descriptions of the flow forming means/wave generator hull and inclined surface of the prior applications should also be read in conjunction with Figures ~~11-30~~ 1-20. However, to the extent there are any differences or discrepancies between the description and teaching of the prior applications and the subject invention, the description and teaching of the subject invention shall prevail.

Except where specifically limited, it is to be understood that the embodiments as described herein are to function in both deep and shallow flow environments. Furthermore, that the flow (except where noted) is to be super-critical (i.e., according to the formula $v > \sqrt{gd}$ where v = velocity, g = acceleration due to gravity ft/sec^2, d = depth of the sheeting body of water).

Description of Shallow Flow Tunnel "Wave" Generator

Turning now to Fig. ~~11~~ 1 (isometric view) and Fig. ~~12~~ 2 (contour map) there is illustrated a Tunnel "Wave" Generator 30 similar to the generator of prior application, however, improved to serve in a shallow water flow. Plan-sectional lines as revealed in Fig. ~~11~~ 1 and contour lines as revealed in Fig. ~~12~~ 2 are solely for the purpose of indicating the three-dimensional shape in general, rather than being illustrative of specific frame, plan, and profile sections. Tunnel Generator 30 is comprised of a stem 31, a front face 32, a stern arch 33, an upstream edge 34 running from stem 31 to stern arch 33 and acting as the upstream perimeter of front surface 32, a downstream edge 35 running from stem 31 to stern arch 33 and acting as the downstream perimeter of front face 32, back surface 36, and sub-surface structural support 37. Front surface 32, bounded by upstream edge 34, downstream edge 35 and stern arch 33 is that feature of Tunnel Generator 30 which effectively shapes its tunnel "wave." Moving in a direction as indicated by arrow 38, super-critical shallow water flow 39 originating from a water source (not shown) moves in a conforming flow upward over the front face 32 to form an inclined body of water in the shape of a tunnel "wave" (not shown) upon which a rider (not shown) can ride. Back surface 36 is sufficiently smooth and with transitions analogous to a conventional waterslide such that a rider (not shown) could safely be swept over or around Tunnel Generator 30 to a termination pool or area (not shown) to properly exit. The outside dimensions of the flow forming front face 32 of Tunnel Generator 30 are capable of a broad range of values which depend more upon external constraints, e.g., financial resource, availability of water flow, etc., rather than specific restrictions on the structure itself. However, for purposes of scale and not limitation, in order to form a tunnel "wave" of adequate size to fully accommodate an adult user, the outside dimensions of Tunnel Generator 30 should be approximately 1 to 3 meters in height and 3 to 12 meters in length.

At least three characteristics of front face 32 of Tunnel Generator 30 influence the size, shape and angle of the tunnel "wave," and each of them interacts with the others:

A. its shape (Fig. ~~11~~ 1 and ~~12)~~ 2);

B. its attitude - its horizontal position or angle with respect to the direction of water flow (Fig. ~~13)~~ 3); and

C. its inclination - its vertical position or angle with respect to the direction of water flow (Fig ~~14)~~ 4).

Each characteristic of front face 32 is now discussed in detail.

A. <u>Shape</u>

Front face 32 of Tunnel Generator 30 has a complex shape comprised of concave curvature, both vertically and horizontally, as indicated generally by the Fig. ~~11~~ 1 plan sections lines and Fig. ~~12~~ 2 contour lines. Such lines are substantially but not specifically illustrative of the range of possible shapes, as will now be explained more fully:

1. Vertically:

a. the shape of the vertical curvature can be:

(1) substantially a simple arc of a circle; or

(2) preferably an arc of a more complex changing curve, e.g.:

(a) ellipse;

(b) parabola;

(c) hyperbola; or

(d) spiral.

If a changing curve, it preferably changes from an opening curve (i.e., the ascending water encounters an increasing radius as it ascends front face 32) at stem 31 through a transition point 40; to a closing curve (i.e., the ascending water encounters a decreasing radius as it ascends front face 32) from transition point 40 to stern arch 33. A critical feature of Tunnel Generator 30 is that commencing at transition point 40, front face 32 begins to curve past the vertical. Curvature past the vertical from transition point 40 towards the stern arch 33 gradually increases from 0 to a maximum of 30 degrees. 10 degrees if preferred.

2. <u>Horizontally</u>

a. The shape of the horizontal curvature can be:

(1) substantially an arc of a circle; or

(2) preferably, a portion of a more complex, changing, curve, e.g.:

(a) ellipse;

(b) parabola;

(c) hyperbola; or

(d) spiral.

~~If a changing curve, it would open (i.e., have an increasing radius from stem to stern) for more rapidly moving water flows, and close (have a decreasing radius from stem to stern) for slower water flows.~~

B. Attitude

As disclosed in Fig. ~~13~~ 3, the horizontal attitude of front face 32 with respect to direction 38 of water flow can vary only within certain limits otherwise the "tunnel" will not develop. Since front face 32 has concave curvature of varying degrees along its horizontal axis, for purposes of orientation an extension of upstream edge 34 is used to indicate varying horizontal attitudes of front face 32 therefrom. Accordingly, upstream edge 34 can vary from substantially perpendicular to the direction 38 of water flow to an angle of approximately 35 degrees, as shown.

C. Inclination

As disclosed in Fig. ~~14~~ 4, the inclination of the front face 32 with respect to the direction 38 of water flow is also limited, otherwise the tunnel will not be developed. Two factors are important with respect to inclination, first, the change in angle of incline relative to the depth of the water must be sufficiently gradual to avoid separation of flow lines/deflection. Second, the angle of release (as defined by a line tangent to front face 32 at downstream edge 35 when compared to the vertical) must be past the vertical as shown. Amounts past vertical may vary, however, a preferred amount is 10 degrees.

At least two other factors effect the size and shape of tunnel wave formation, i.e., flow velocity and water flow depth. The velocity of the water over Tunnel Generator 30 has a wide range, dependent upon the overall size of the Tunnel Wave Surface and the depth of water. In general, the flow is to be super-critical (i.e., according to the formula $v > \sqrt{gd}$ where v = velocity, g = acceleration due to gravity ft/sec^2, d = depth of the sheeting body of water). However, velocities in excess of that which is at a minimum necessary to achieve supercritical velocity are sometimes desired, e.g., to provide sufficient momentum transfer to support the weight component of a given rider, and to achieve the vertical heights required to form a tunnel "wave."

The depth of the water is primarily a function of the minimum necessary to permit a tunnel "wave" to form at a given height, and simultaneously enable the flow of water to support (via momentum transfer) the weight component of a contemplated range of users. Because of the operational requirements of momentum transfer, the depth of the water has direct relationship to the velocity of the water, i.e., the higher the velocity of flow, the

lower the requisite depth. Since this embodiment is limited to shallow flows, the depth of water will range from approximately 2 to 40 centimeters.

Tunnel Generator 30 can be fabricated of any of several of well known materials which are appropriate for the use intended. Concrete; formed metal, wood, or fiberglass; reinforced tension fabric; air, foam or water filled plastic or fabric bladders; or any such materials which will stand the structural loads involved. A preferred embodiment includes a thick foamed plastic covering to provide additional protection for the riders using the facility.

Theoretically, no pool or water containment means is required for Tunnel Generator 30, in that the flow from a suitable flow source (e.g., pump and nozzle, fast moving stream or elevated reservoir/lake) is all that is required. However, where water recycling is preferred, then, low channel walls can be constructed to retain the flowing water with a lower collection pool, recycling pump and appropriate conduit connected back to the upstream flow source. The area of channel containment need be only large enough to allow the performance of appropriate water skimming maneuvers, since the curling water of the tunnel wave would remain more or less stationary with respect to the containment structure. Thus, such a structure could be constructed even in a backyard.

From the description above, a number of advantages of Tunnel "Wave" Generator 30 becomes evident:

(a) The energy required to produce a tunnel "wave" shape under shallow flow conditions is dramatically less than that required under "natural" conditions, e.g., as indicated in Killen's 1980 article, the power required to produce operational natural waves is proportional to the height of the wave raised to the 3.5 power ($hw^{3.5}$). Consequently, a 2 meter wave would require 11.3 times the power of a 1 meter wave or approximately 3.7 mega watts or 4800 horsepower. An 8 cm in depth shallow flow wave as contemplated by the subject invention with similar width to Killen's structure would be able to produce a 2 meter high tunnel "wave" for under 400 horsepower.

(b) The capital costs and operating costs for shallow water tunnel "wave" generation is substantially less than deep water installations.

(c) The sight, sound, and sensation of tunnel "wave" riding is a thrilling participant and observer experience, that has heretofore only been available to relatively few people in the world. The subject invention will enable this experience to become more readily available.